Reliability Evaluation of PEMs Rejected During C-SAM Examination

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Purpose and Outline

Purpose:

To discuss effectiveness of C-SAM examinations during screening of low-power devices in SOIC8 packages and power devices in TO-220 and SOT-223 style packages.

Outline:

- General problems with C-SAM.
- Description of C-SAM rejects used for experiments.
- Reliability testing conditions and results.
- Conclusion.

Which Part to Choose?

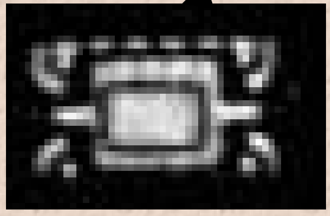
Delaminations are due to stress relief in PEMs.

Typically rejected

Before stress. After stress?

This part might operate reliably because mechanical stresses have been relieved and delaminations are stable.

Typically accepted



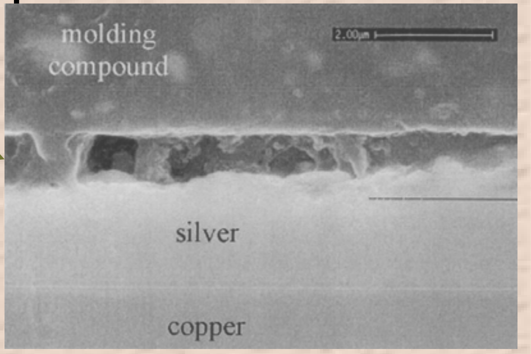
Before stress. After stress?

This part might fail if the stresses have not been relieved and delaminations develop in critical wire bond areas.

- Some types of delaminations might be not harmful.
- If delaminations are serious defects, is it possible to improve reliability of a lot with 5% to 50% rejects by screening?

More Provocative Questions Regarding Acoustic Microscopy

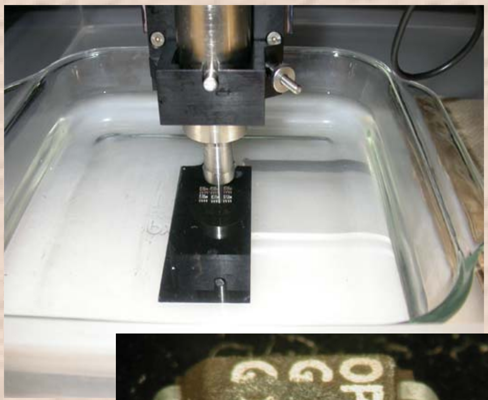
- If no delaminations were observed by screening:
  - Can they appear after soldering reflow, TC, environmental stresses, operation, …?
  - Can they develop reversibly at high/low temperatures or during moisture sorption/desorption?
- What if there is a sponge-like structure at the interface?

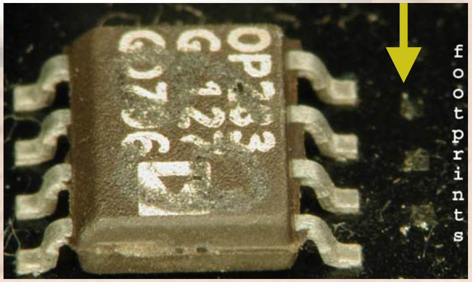


- How reliable is C-SAM data?
- How often do delaminations self-heal?
- How risky are different types of delaminations?

Is CSAM Testing Non-Destructive?

- Each handling has the probability of ~0.1% of ESD damaging the parts. This number might be larger for low voltage microcircuits.
- Requirements for the cleanliness of water are not always enforced.
- To screen large-quantity lots, the parts are installed on a sticky plate. This might contaminate leads and mechanically damage small parts.
- Special holders to avoid damage are not always available.



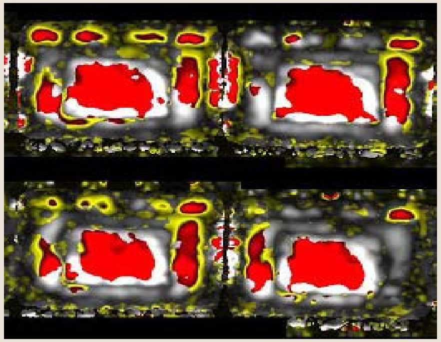
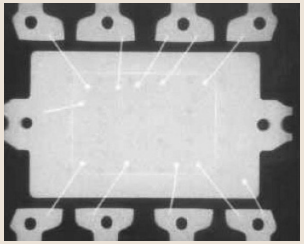
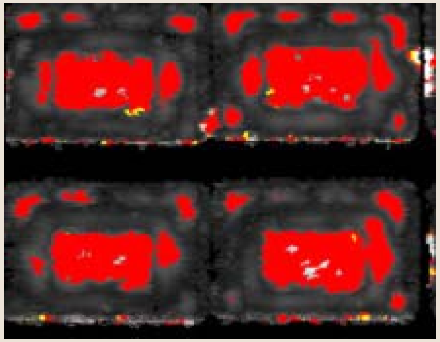
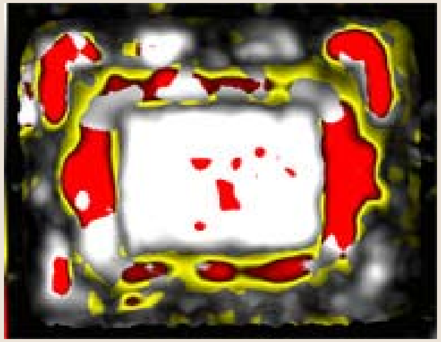
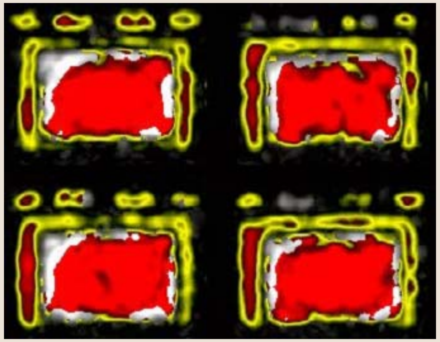


Description of Parts Used

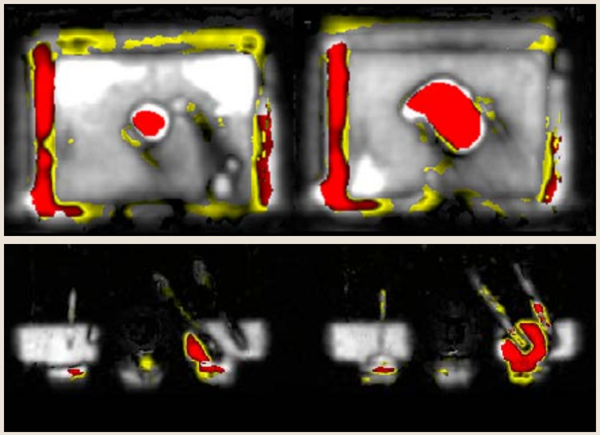
Part	Package	Die coating	Total QTY	Rejects, %	Type of delam.
PEM1	SOIC8	silicone	712	83%	P, L
PEM2	SOIC8	silicone	469	20%	P, L
PEM3	SOIC8	silicone	2143	5.1%	P, L
PEM4	SOIC8	-	463	32.2%	P, L
PEM5	SOIC8	silicone	297	18.9%	P, L
FET1	D2pak	-	995	14.6%	P, L, D
FET2	D2pak	-	200	28%	P, L, D
FET3	SOT223	-	895	10.5%	P, L

Delaminations:
P - top of paddle; L – leads at wire bonds; D – top of die.

Typical AM Images (Linear Devices, SOIC8 Packages)

 PEM1	 PEM2	 PEM2 had 2 WBs to the paddle, which might cause failures if broken.
 PEM3	 PEM4	 PEM5

Typical AM images (Power FETs)

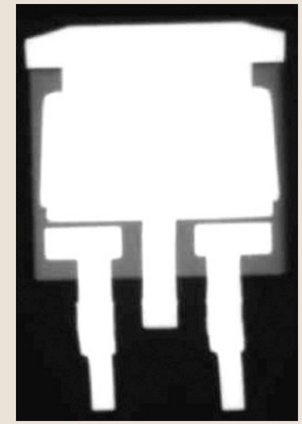


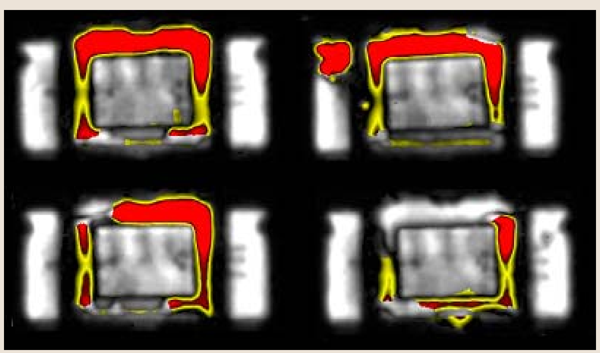
FETs 1 and 2 have
Al wire bonds.

Characteristics of
molding compound:

Tg = 165 °C

CTE1 = 21.5 ppm/°C



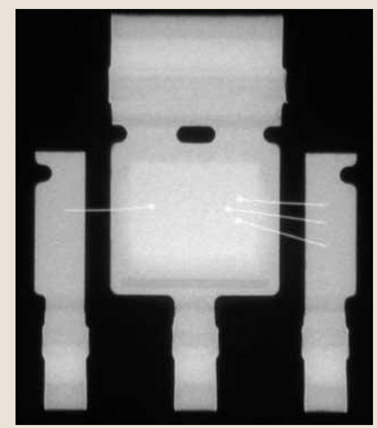


FET3 has
Au wire bonds.

Characteristics of
molding compound:

Tg = 155 °C

CTE1 = 16.4 ppm/°C

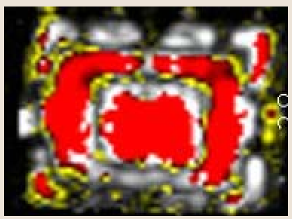
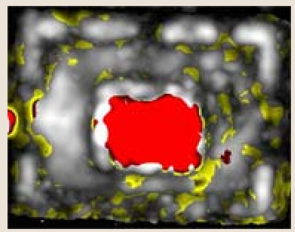
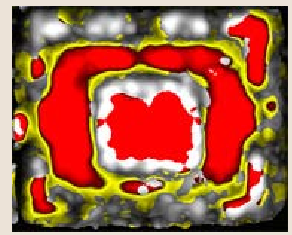
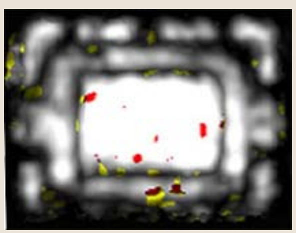
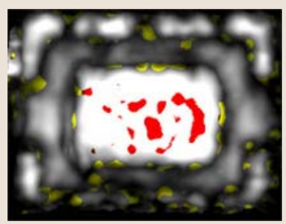
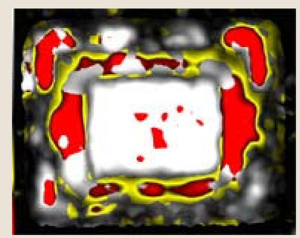
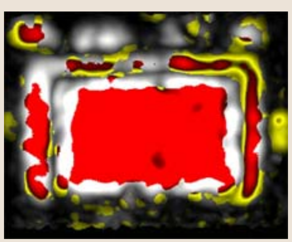
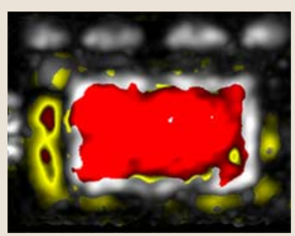
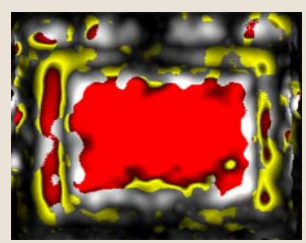


Testing of AM Rejects

Thirty samples of each part type rejected by C-SAM screening were electrically tested, environmentally stressed, and examined using acoustic microscopy:

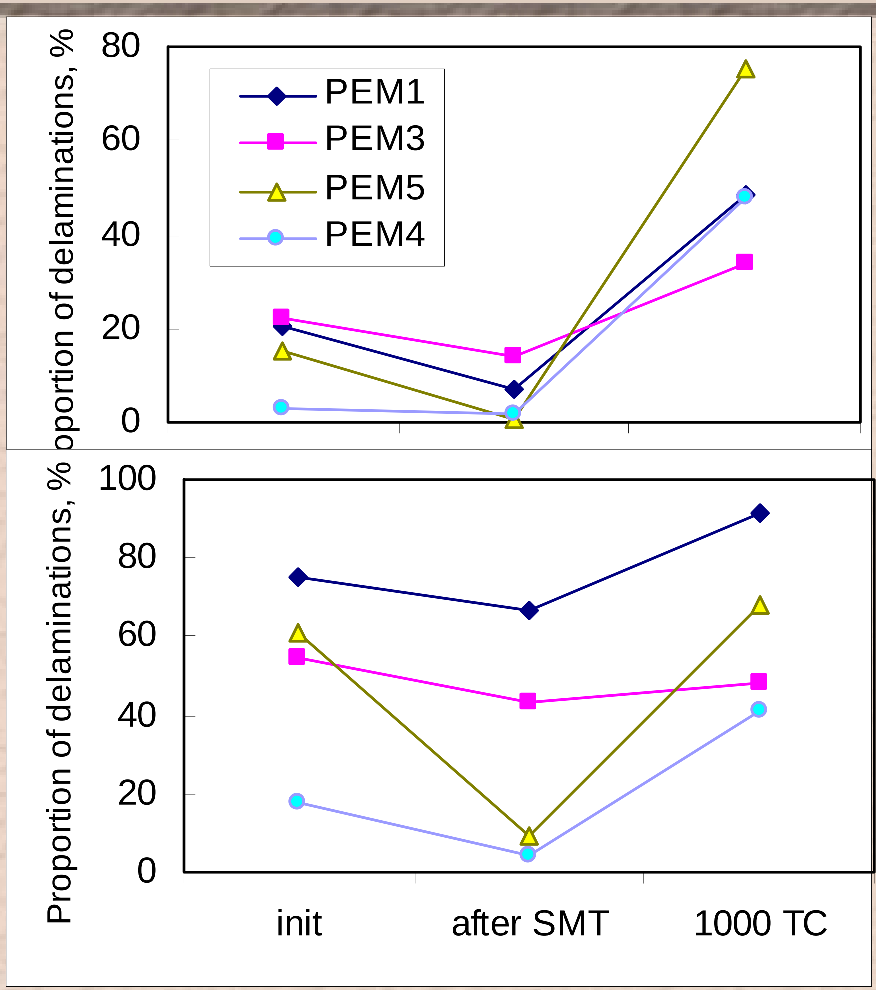
- Before testing.
- After SMT simulation and preconditioning per JEDEC JESD22-A113 (85 ^{o}C/85% RH/168 hrs +3 runs through IR reflow chamber+ flux application and rinsing).
- After 100, 300, and 1000 temperature cycles between –55 and +125 ^{o}C (condition TC0).
- After 100 and 300 cycles between 0 and 180 ^{o}C (condition TC1).
- After 100 and 300 cycles between 20 and 200 ^{o}C (condition TC2).

Examples of AM Images Before and After Stress Testing (Linear Devices)

	init	after SMT	after 1000 TC
PEM1			
PEM4			
PEM5			

The proportion of delaminated area decreased after SMT and increased after temperature cycling.

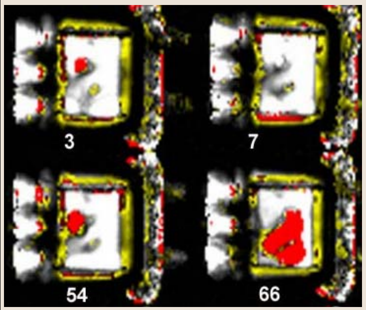
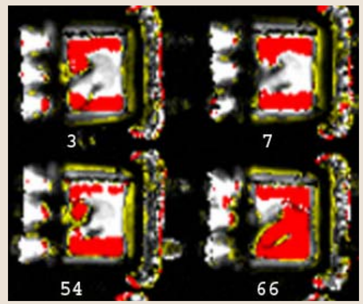
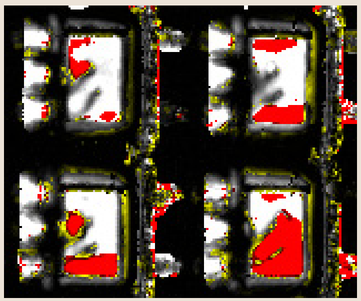
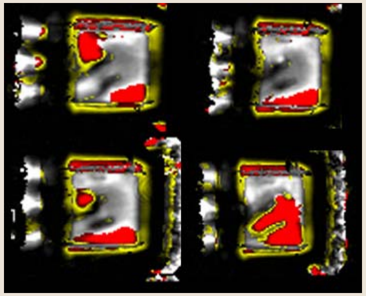
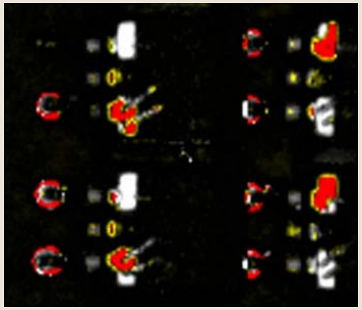
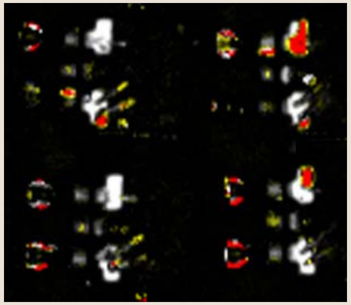
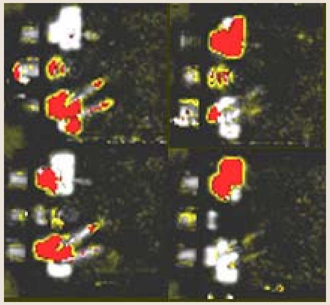
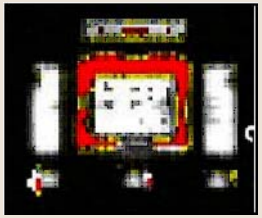
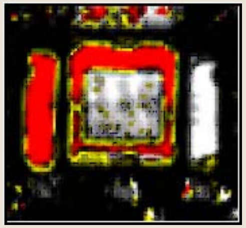
Changes in Delaminations Due to Stress Testing (Linear Devices)



Lead-to-MC delaminations

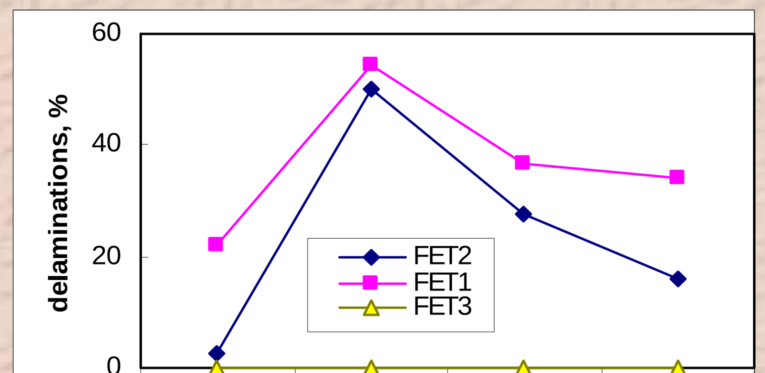
Paddle-to-MC delaminations

Examples of AM Images Before and After Stress Testing (Power Devices)

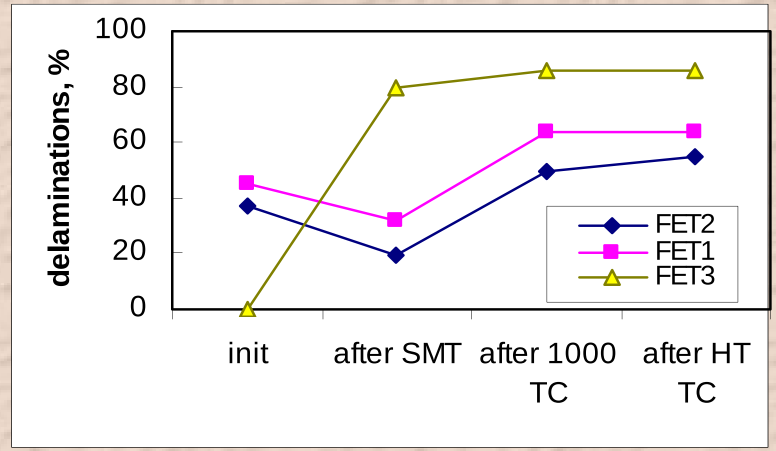
	init	after SMT	after 1000 TC	after HT TC
FET 1die				
FET 1 lead frame				
FET 3				

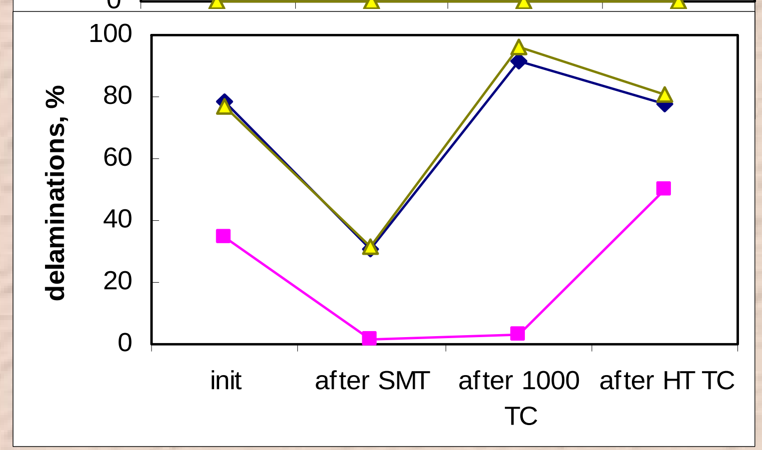
Changes in Delaminations Due to Stress Testing (Power Devices)

Die surface



Leads



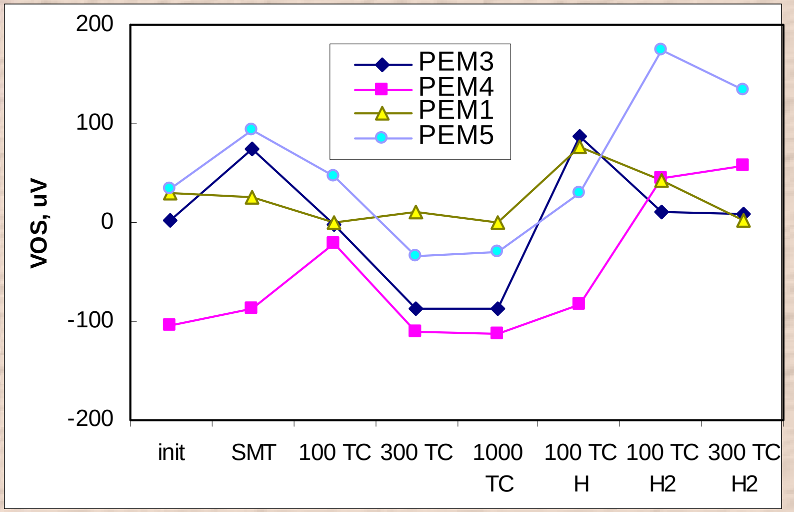


Top paddle

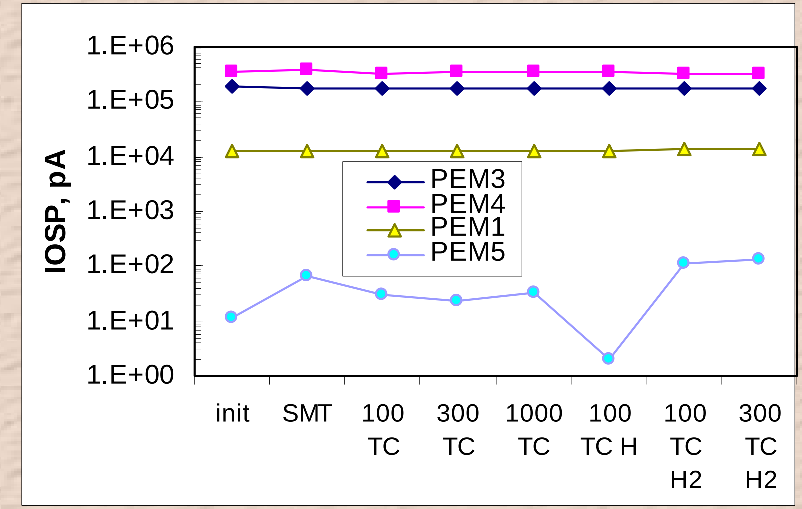
- No top-of-die delaminations (TODD) in FET3.
- In FETs 1 and 2 TODD increased and paddle delaminations decreased after SMT.

Results of Electrical Testing (Operational Amplifiers)

Offset voltage variation during temperature cycling

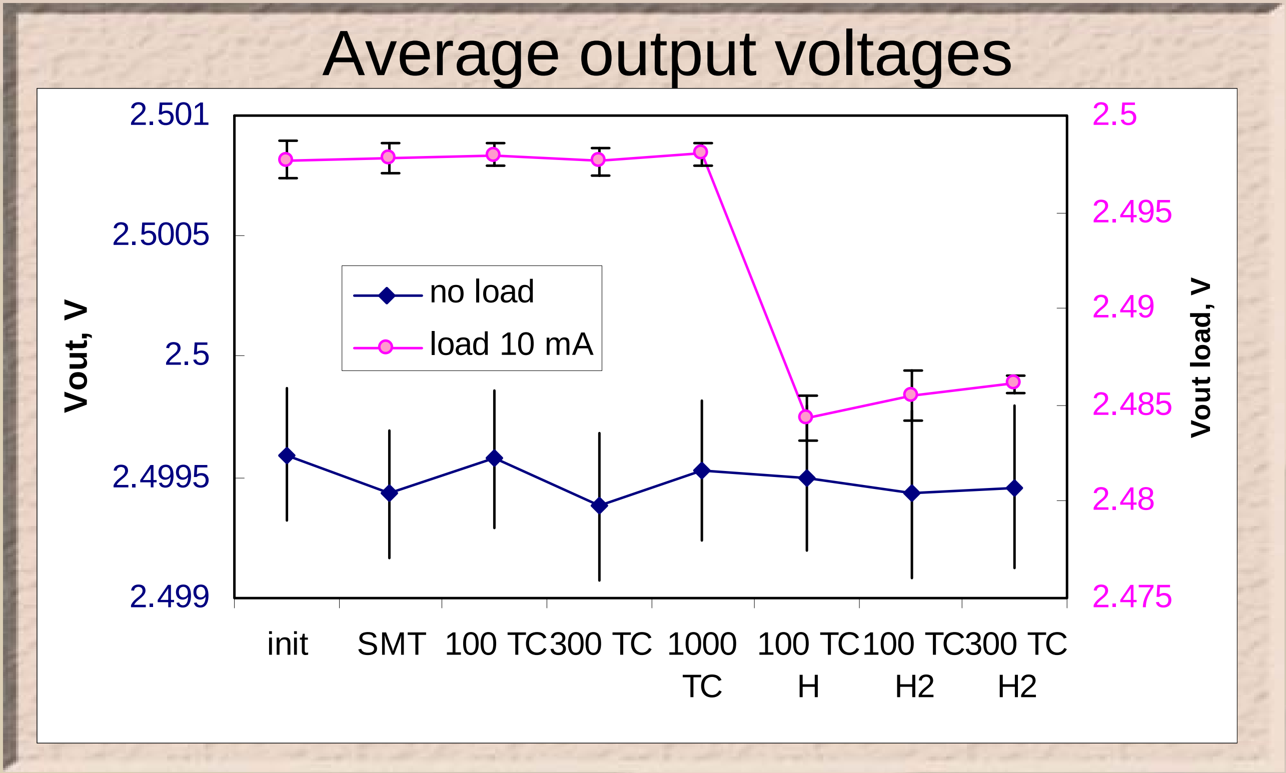


Input bias current variation during temperature cycling



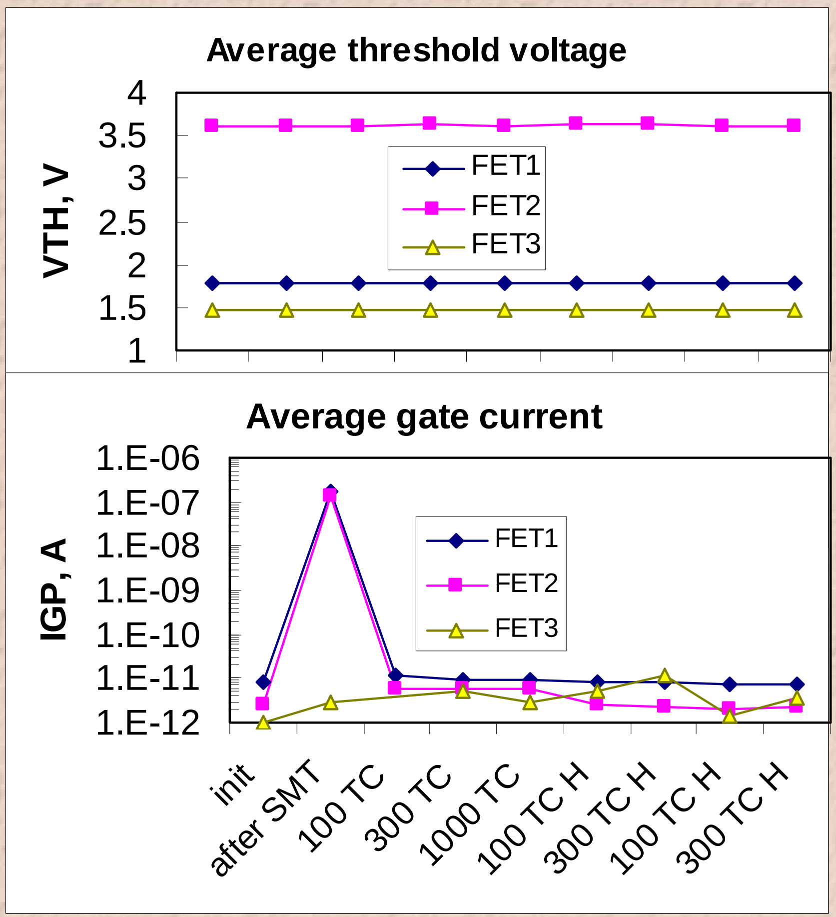
The parts had no failures and manifested only minor parametric variations.

Results of Electrical Testing (Voltage References)



- Devices had minor parametric variations.
- One part failed at load conditions after 100 HT TC.

Results of Electrical Measurements (Power FET)



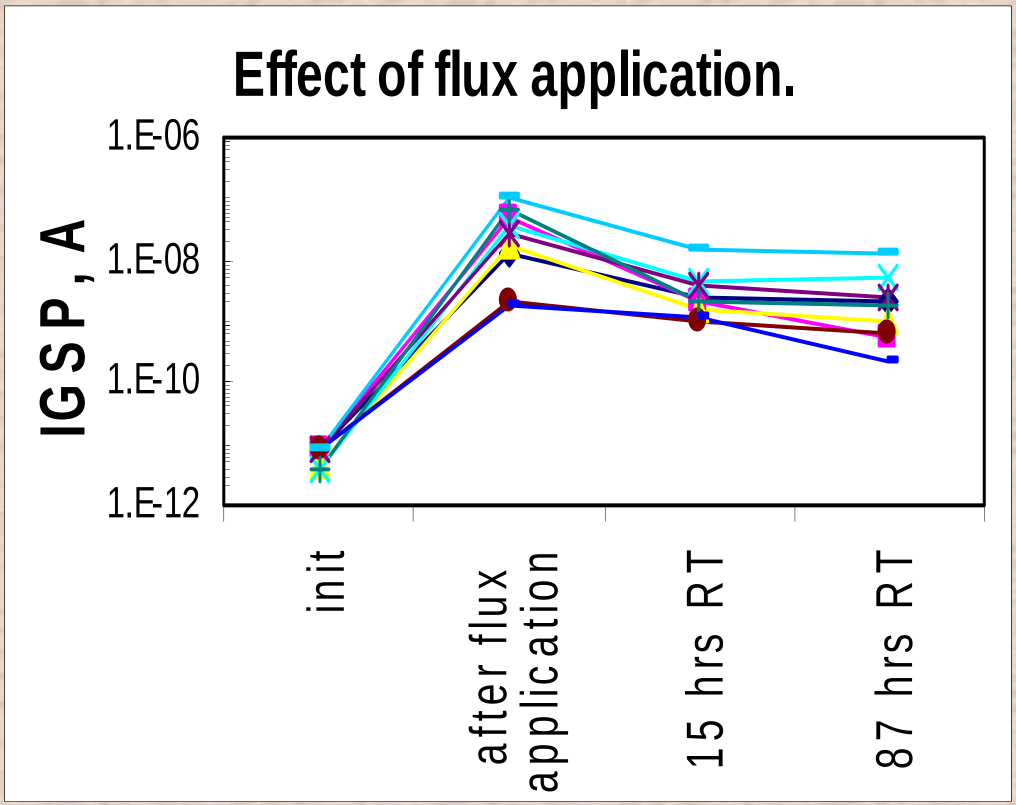
- No failures after TC.
- No VTH variations.
- Significant increase in leakage currents after SMT simulation.
- All failed parts recovered after TC.
- Some failed parts had corrosion of Al metallization after HAST.

Results of Temperature Cycling of Parts with Excessive Delaminations

Part	SMT	TC0 100	TC0 300	TC0 1k	TC1 300	TC2 300
PEM1	0/30	0/30	0/30	0/30	0/15	0/15
PEM2	0/30	0/30	0/30	0/30	1/15	1/15
PEM3	0/30	0/30	0/30	0/30	0/15	0/15
PEM4	0/30	0/30	0/30	0/30	0/15	0/15
PEM5	0/30	0/30	0/30	0/30	0/15	0/15
FET1	0/30	0/30	0/30	0/30	0/15	0/15
FET2	0/30	0/30	0/30	0/30	0/15	0/15
FET3	0/30	0/30	0/30	0/30	0/15	0/15
PEM6*	0/30	0/30	0/30	0/30	-	-

*Parts had excessive delaminations at finger-tips after HAST.

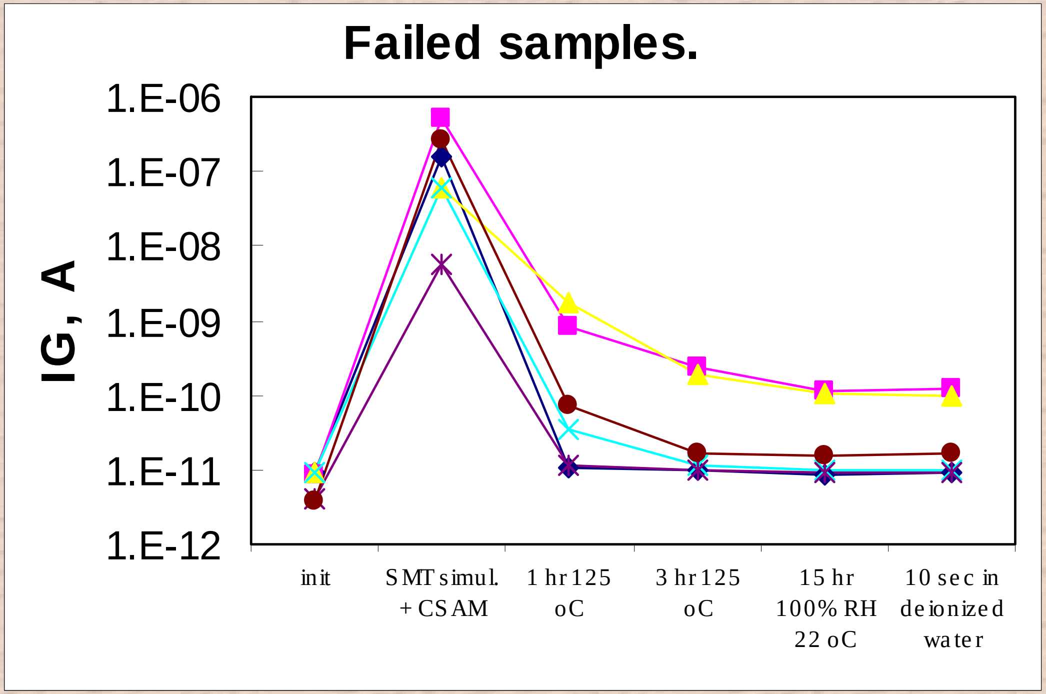
Effect of Flux Application on Power Devices



<u>Test conditions:</u> Immersion into KESTER 2331-ZX water-soluble flux for 10 seconds, rinsing, and blowing with dry air.

Excessive leakage currents remained after a few days of storing in laboratory conditions.

Effect of Flux Application on Power Devices, Cont’d

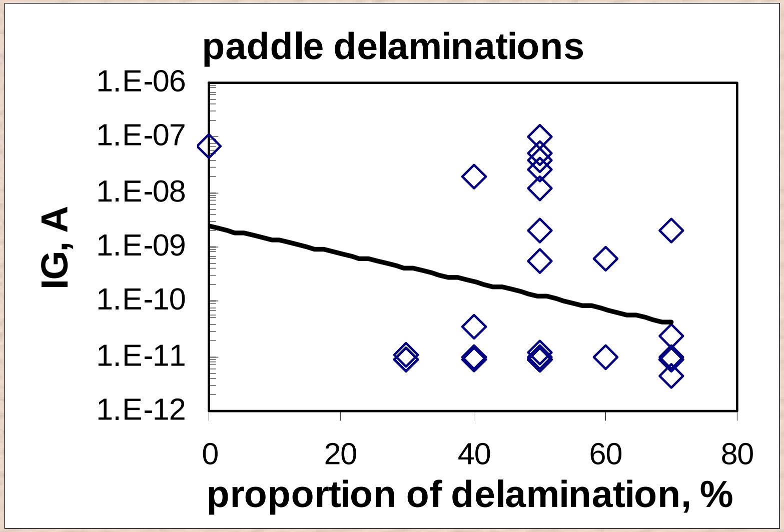


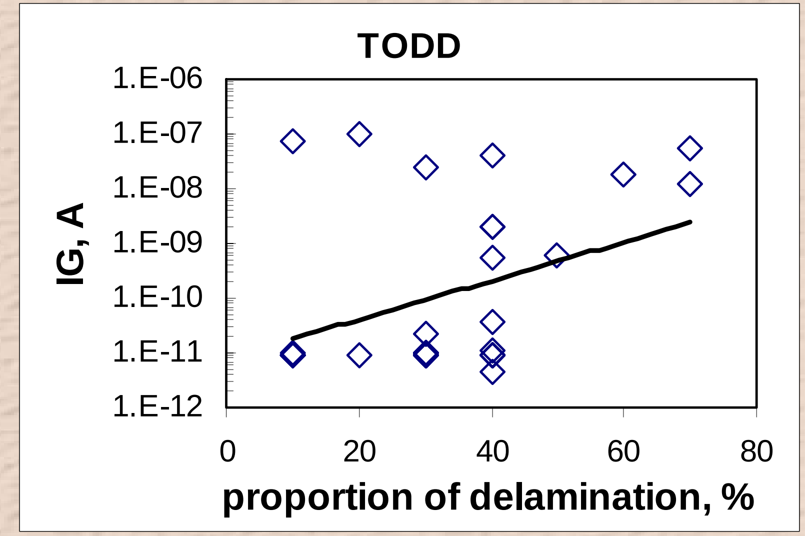
- Baking for a few hours at 125 ºC mostly restored leakage currents.
- Immersion in water and storing at 100%RH did not increase IG.
- Effect of SMT simulation is likely due to good wettability of flux.

- The type of flux used for SMT simulation might affect results of qualification testing. JESD22-A113 might need a review.
- Flux used for soldering might be different from the one used for the simulation, thus making results of qualification questionable.

Can CSAM Screen Out Flux-Related Failures?

Effect of immersion into flux





No correlation between TODD or paddle-to-MC delaminations and leakage currents after flux immersion was observed.

Conclusion

- Parts with excessive delaminations at the paddle and leads (at secondary bond locations) had no electrical failures after 1000 TC at –55 to +125 ºC conditions.
- The analyzed power devices in TO220-style packages are prone to formation of top-of-die delaminations; however, no wire bond fractures occurred even after multiple temperature cycling.
- Washable flux can penetrate to the die surface through delaminations significantly increasing leakage currents and causing corrosion of Al metallization.
- No correlation between the proportion of delaminations and flux-induced leakage currents were observed indicating a failure of CSAM examination to screen out potential failures.
- For the part types used, CSAM examination is not a value-added technique for screening; however, it is very useful for qualification testing.